THE UNIVERSITY OF TEXAS AT AUSTIN

REPORT ON THE LUNAR RANGING at MCDONALD OBSERVATORY FOR THE PERIOD SEPTEMBER 10, 1972 TO DECEMBER 5, 1972*

by

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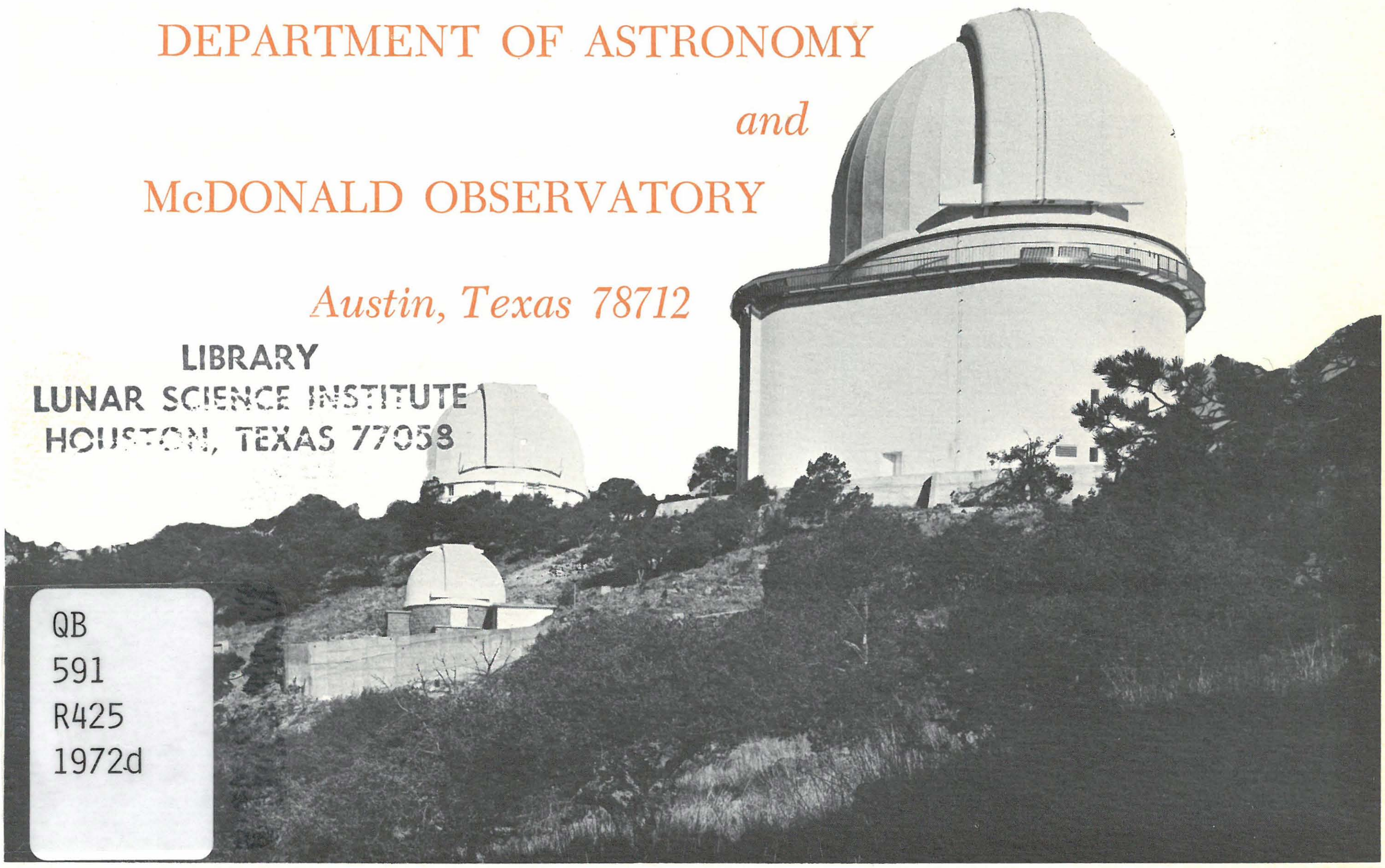

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ABSTRACT

Due to the installation of a spur gear drive on the 107" telescope, the lunar laser system only operated for about six weeks of the previous quarter. During that shortened operation changes were made in the dark room guiding enabling the average signal to be greatly increased.

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I. OPERATIONS DURING THE QUARTER

A) Ranging Efforts

This quarterly report covers the three lunations which occurred between September 10 and December 5, 1972. During this period the lunar ranging efforts were greatly abbreviated by the installation of the spur gear drive system on the 107" telescope. The installation itself took over six weeks of the middle of this reporting period. During that time the laser operating crew was assigned to the engineering staff to help expedite the changeover. Thus, for the first time in over three years the experiment missed firing at the moon for one entire lunation. In addition, the inevitable start-up difficulties associated with such a drastic change lowered the efficiency of the ranging efforts for the last two weeks of the quarter. With this explanation behind, we state that the data output from the quarter consists of about 40 good measurements from the September lunation and about 12 of lower quality in late November out of a total of 71 attempts. Most of these ranges were measurements to the Apollo 15 corner and are believed to be typically of 10 - 15 cm accuracy. As usual, a day by day log of the lunar firing is contained in Appendix I. It is noteworthy that the month of September was the most successful to date with regard to the overall average signal.

B) Technical Improvements

With the exception of the spur gear, which we shall discuss separately, the only significant improvement in operation concerned the method of guiding the dark moon range measurements. Since the dust has not yet settled with regard to the new procedures we will only give a rough outline in this report and leave the detailed documentation for a later time.

Prior to September of this quarter nearly all of the dark moon guiding was done by use of the computer pointing capabilities of the 107" telescope. On-line software carried by the observatory IBM 1800 computer allowed the telescope to be automatically moved for short distances in both coordinates corresponding to the separation between a visible lunar feature and the desired corner reflector site. This method rarely attained the desired signal strengths through three years of ranging.

The reason for the failure of the computer offset methods was probably due to the lack of a feedback on the pointing which is available during visually guided operations. Thus, when the upstairs guide station was installed in February of 1971 provision was made for a wide field of view and accurate offset capability through a rotating x-y stage. Unfortunately, the difficulties of making accurate offsets on a rotating field whose position varies nightly was not fully appreciated during the design of the guide station. It was not until late last summer that the methods for calibrating and using rotating coude stage became clear enough to make it a useful tool.

The present operation calls for the laser operator to measure the position of the laser retro return at a couple of selected positions near the beginning of every laser run. He then inputs this information to the IBM computer where it is interpreted and stored for later use in the crater offset programs. Angular information on the stage rotation is soon returned as well as some test points to check the accuracy of the stage constants. The computer can then accurately predict the correct offset to lunar craters which lie within the field of view. The method proved successful beyond hope during the September lunation and was primarily responsible for the high average signal. For the first time we were able to acquire unilluminated corners with a signal strength comparable with the visual guided runs. We would anticipate on the basis of this rather short trial that the offset stage will completely replace the computer drives for our dark moon ranging efforts.

C) Spur Gear Installation

Like the new guiding methods, the result of the spur gear modification to the 107" telescope has yet to stand the test of time. Since the success or failure of the various aspects of this system will affect the laser ranging experiment for some time, we feel a brief description is in order.

The spur gear drive is a system which was designed by J.E. Floyd to replace the worm gear, damaged during installation almost four years ago. The system senses the position of the telescope axes by the use of a roller pickoff and accurate digital tachometers, and uses this information to control torque motors operating on the old preload gears of the telescope. The advantages which relate directly to laser are the following: much higher slew rates greatly decreasing the set-up time during laser runs; and a high potential for good differential offsets over short arcs. The disadvantages (some of which may be temporary) are as follows: the necessity of developing new files for removing the cumulative effects which we call flexure; and less accurate absolute pointing.

We have used the spur gear drive system for about 10 laser runs at this writing. The performance on visually guided runs differed little from the previous system. We did not, at that time, have a computer drive capability and thus could not evaluate its performance for use with any dark moon runs. We would anticipate, however, that by using the offset guiding we will be able to operate per usual for most of the month. The one area which will cause some difficulties is the temporary lack of good absolute positioning.

This will undoubtedly cause some slowness and possible misidentification of features on the thin crescent near the new moon period.

D) Miscellaneous

During the spur gear installation the primary and first diagonal mirrors of the 107" were realuminized. We do not have good estimates of the relative transmission gain due to some changes in our own photometer during the break, but the signal does appear to be quite good. Earlier we also made reference to the fact that our operating efficiency was relatively poor after the start-up, restricting use to the Apollo 15 corner. This difficulty in operation was caused by a problem with the #3 mirror support system as evidenced by a large astigmatism in the image. Although the loss of signal due to the astigmatism was small, the seeing not being exceptional during the period, the day to day work on the optics did not allow us to stabilize the system in time to prepare for the large and demanding offsets near new moon. This problem has been cured.

The following sections in this report describe a small correction to the calibration data of the last three months as well as a mechanism to provide redundance on the calculation of the calibration constants. They are a necessary part of the system documentation but only of passing interest to those investigators who do not work directly with the magnetic tape data.

II. DATA REDUCTION NOTES

A) Correction to Previous Calibration Constants

Problem: During the period covering from June 9, 1972 through October 3, 1972 improper vernier constants were used to convert the a to d voltage readings to the time-of-flight values. The result was an error in the calibration constants, as originally transmitted on the data cards, of approximately 440 picoseconds. Appendix II contains an ammended list of calibration constants for the period in question. Note that the error margins have been slightly increased for the entire data set to allow for the uncertainty in recovery. A brief description of the problem is included below.

Explanation: The vernier contribution to the measured lunar range, as well as the contribution to the calibration range, is normally calculated from two analogue voltages, V0 and V1, by multiplying these voltages with the appropriate constant. During the period from June to October, 1972 the formula used to convert the vernier readings to ranges read like:

$$.04765 * V0 - .048750 * V1 = \text{range (nanoseconds)} \quad (1)$$

where: V0 and V1 are dimensionless numbers indicating the digital equivalent of the vernier voltages. The correct formula which should have been used during this period is:

$$.04860 * V0 - .04800 * V1 - 3.33 = \text{range (nanoseconds)} \quad (2)$$

The multiplication factors contained in these equations are derived from a least squares fit of the verniers over 100 shot calibration runs, taken such that the total vernier contribution should equal zero. A temporary and erroneous modification of this program caused it to suppress the additive calibration constant at the expense of a larger multiplication factor on the second vernier reading. Thus, the vernier constants used over a several month period beginning in the summer of '72 were not true representations of the proper conversion constants.

Since the same vernier formula is used for both the calculation of the lunar range as well as for the calibration constant, an error in the multipliers does not strongly affect the accuracy of the corrected range. In fact, an error in either the V0 multiplier or the additive constant will not be important until it adds jitter to the lunar ranges. The same is not true of the V1 multiplier. Due to the delays present in the lunar ranging electronics, the value of V1 is systematically 30 nanoseconds lower when measuring calibration ranges rather than the lunar returns. Thus, an error in the V1 multiplier will affect the final range in the magnitude of 30 nanoseconds times the percentage error in the V1 multiplier. This produced a calibration constant which is estimated to be 440 picoseconds too high during the period in question. The uncertainty in this number is caused by our inability to completely recover the proper vernier constant in the amount of approximately ± 250 picoseconds.

Recovery: Two levels of recovery are possible. The simplest is to use the originally supplied vernier constants, equation 1, to determine the lunar ranges, and systematically change the electronic constants by 440 picoseconds as shown in Appendix II. The second level of recovery (for the purist only) would involve developing new lunar ranges as well as new electronic calibration constants using the vernier multipliers in equation 2 and the data on the magnetic tapes. The method of developing calibration constants using the data contained in the magnetic tapes is the subject of Section II-B.

Cure: In order to lessen the effects of the varying vernier constants we will add a delay to the start side of the system such that the verniers are used in the same range on both lunar and calibration measurements.

B) The Calculation of Calibration Constants from Magnetic Tape Data

The present system for processing the magnetic tapes containing the lunar range data works around the following basic points. Magnetic tapes are sent monthly to the University of Texas at Austin accompanied by a log sheet and machine readable cards containing environmental data, the calibration constants, and any suspected range measurements. The time of flight of each lunar range return is calculated from the magnetic tape by adding two vernier readings and a digital measurement from a 50 nanosecond time interval counter. To this one adds the calibration constant, which is read from the machine readable cards, producing the corrected lunar range measurements. The calibration correction is evaluated by the lunar ranging crew. It is an arithmetic average of the calibration numbers as printed in real time by the on-line computer.

The present method of producing calibration constants is probably best continued since it forces an awareness at the lunar ranging site as to the accuracy and consistency of the calibration numbers. Furthermore, the calibration constants which are produced are probably good to 300 picoseconds, well within the accuracy needed at the present time. The purpose of this section is to point out that <u>calibration constants can be recovered to higher accuracy by the use of data which is written on the magnetic tapes.</u> This magnetic tape calibration constant could be useful to reduce the lunar range data to higher accuracy, as a better ephemeris becomes available, or to check on the off-site-developed calibration constant in the event of a range fit disparity.

Each shot of the laser causes a record to be produced on the magnetic tape which is in the format shown on the following page. The shots of a particular laser run are grouped into records of 100 words and written onto magnetic tape following each burst of 50. You will note that the record contains space for three vernier readings, 0, 1, and 1' in words 10, 11, and 12 respectively. Vernier 0 contains the results of firing the first time to pulse height converter, which measures the time from the actual firing of laser to the first of our 50 nanosecond clock pulses. Those clock pulses are counted by a time interval meter (TIM) until the return signal appears and vernier 1 is activated. Vernier 1 then measures the time between the return signal and the next 50 nanosecond clock pulse. If no lunar return or noise stop occurs, the second vernier, V 1, is read as zero. The lunar range is calculated by combining the results of V 0, V 1, and TIM readings in the following fashion:

TIM * 50 + K0 * V0 - K1 * V1 + K2 = RANGE (nanosecond)

where: K0, K1, and K2 are vernier calibration constants normally supplied by the lunar ranging crew. In as much as the Varian computer carries the same vernier constants as later used by the reduction group in Austin, the real time residuals will agree with the final results if the same predicted range is used.

RANGING DATA LASER SHOT FORMAT

Legend: 0 = Always 0

1 = Always 1

X = 0 or 1

N = Shot Number

Word No.	Bit Description	Symbol	Word	Form
14(N-1)+1	0000 00XX XXXX XXXX	Day 1	Day, GMT	BCD
2	00XX XXXX 0XXX XXXX	HM1	Hour & Minute, GMT	BCD
3	0000 0000 0XXX XXXX	SEC1	Second	BCD
4	0XXX XXXX XXXX XXXX	RB1	Time interval meter 1	BCD
5	XXXX XXXX XXXX XXXX	RB2	Time interval meter 2	BCD
6	XXXX XXXX XXXX XXXX	RB3	Calculated range 1 nanosecond	BIN
7	0000 0000 00XX XXXX	RA1	Projected range 1	BCD
8	XXXX XXXX XXXX XXXX	RA2	Projected range 2	BCD
9	XXXX XXXX XXXX XXXX	RA3	Projected range 3	BCD
10	XXXX XXXX XXXX 0000	V0	Initial vernier	BIN
11	XXXX XXXX XXXX 0001	V1	Final vernier	BIN
12	XXXX XXXX XXXX 0001	V1'	Calib vernier	BIN
13	0000 00XX XXXX XXXX	EP1	Firing Epoch 1	BIN
14	0000 00XX XXXX XXXX	EP2	Firing Epoch 2	BIN

EP1 contains 2^{19} through 2^{10}, EP2 contains 2^{9} through 2^{0}.

In the event that a laser shot is fired and no noise pulse or lunar return is detected, we require no character printout in the real time ranging system. In that event the dead time may be used to type calibration ranges. The calibration ranges are calculated by using verniers 0 and 1 to measure a small, three foot range during the firing of the laser. The shortness of the calibration range measurement does not require the use of the TIM, thus freeing it for counting the 50 nanosecond pulses until the return of the lunar range some 2-1/2 seconds later. The calibration range does, however, require an additional reading of vernier 1 directly after the lunar range electronics has recorded the value of V0. The calibration constant can be calculated by the following formula:

$$K0 * V0 - K1 * V1' + K2 - 2.9 = CALIB \text{ (nanosecond)}$$

where: the constants, K0, K1, and K2 are the same as those which are used for the calculation of the lunar range; and an additional 2.9 nanosecond correction is needed due to the difference in path lengths between light returning from the lunar surface and that which is deflected for the purposes of calibration.

The additional reading of the first vernier, V1', is stored on the magnetic tape in position 12. It is available for recalculating the calibration constants at a later time. The calibration calculated from the magnetic tapes at a later date, will have several advantages over the number which is supplied by the real time printouts on machine readable cards. 1) The calibration constants calculated from the magnetic tapes can take advantage of all of the calibration stops which have occurred in any ranging. Since the Varian computer only prints out the calibration number when it does not receive a noise or a lunar return, some of the calibration returns are missed and do not enter into the calculation of the constants applied on cards. 2) The data reduction team can take into account the exact effective pulse shape as it appears on the system electronics for use in developing the normal points for the final data distribution. This should provide a more effective means of pulse width averaging that the simple arithmetic mean which is normally used to determine the calibration constant. 3) The data reduction team can independently derive the constants K0 and K1 by requiring that the effective system jitter be reduced to a minimum in the calibration data. Thus, at least in theory, a data reduction team can independently solve not only for the calibration constant but also for the vernier constants by using any substantial subset of the lunar range data. The additive constant, K2, enters identically in both the calculation of the calibration range and the final lunar range and, thus, does not have to be known. We would caution, however, that the solution for K0 and K1 developed by minimizing the spread in the calibration data may employ slightly different areas of the stop and start verniers than will the final lunar range. Thus, any solution developing the constants by this method should be accompanied by frequent, on-site verifications of the linearity of the two verniers.

We would recommend that the data reduction from magnetic tapes include at least spot checks of the calibration constants in order to insure that the on-site methods are proceeding properly. Furthermore, we would also recommend that some very high accuracy normal points be developed, using the exact calibration profile whenever the statistical average of the lunar returns is good enough to warrant the added effort.

APPENDIX I

DAILY OPERATING LOG

SEPTEMBER 11, 1972 TO DECEMBER 5, 1972

STATION LOG, SEPT. - OCT. 1972

DATE	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING(")	COMMENTS
Sept. 11	13:30				cloudy		run cancelled
	16:30				cloudy		run cancelled
	19:30				cloudy		run cancelled
Sept. 12	14:20				cloudy		run cancelled
	17:20				cloudy		run cancelled
	20:20				cloudy		run cancelled
Sept. 13	16:20				cloudy		run cancelled
	20:20	(409)	50/0	0/0	clear	4	run shortened because telescope stopped tracking.
Sept. 14	17:00				raining		run cancelled
	20:20	(410)	500/0	0/0	clear	3	
Sept. 15	18:00-22:00				clouds		runs cancelled
Sept. 16	19:00-23:00				clouds		runs cancelled
Sept. 17	20:00-21:05	(411)	70/3	10/3	clear	3	
		(412)	260/2	10/2	"	"	
		(413)	100/0	6/0	"	"	
		(414)	30/3	10/3	"	"	
	00:00-00:25	(415)	250/3	5/3	clear	5	
Sept. 18	19:20				cloudy		run cancelled
	22:20-23:10	(416)	85/3	10/3	clear	4	
		(417)	210/2	10/2	"	"	
		(418)	200/0	0/0	"	"	
		(419)	100/3	6/3	"	"	
	01:00				clear		run cancelled due to high humidity.
Sept. 19	20:00				clear		run lost due to alignment troubles.
	23:00				cloudy		run cancelled
	02:00				cloudy		run cancelled
Sept. 20	21:00-04:00				cloudy		runs cancelled
Sept. 21	22:00-05:00				cloudy		runs cancelled
Sept. 23	22:30				cloudy		telescope down

STATION LOG, SEPT. - OCT. 1972

DATE	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Sept. 23	01:30				cloudy		telescope down
	03:00				clear	5	used for pointing tests
Sept. 24	23:30	(420)	220/3	12/3	clear	2	10 in last 80
	02:30	(421)	100/3	16/3	clear	2	
		(422)	50/0	6/0	"	"	
		(423)	150/2	8/2	"	"	
		(424)	60/3	0/3	"	"	lost laser flashlamp
Sept. 25	00:30	(425)	100/3	10/3	ptly cldy	1	only 50% transmission
		(426)	150/0	7/0	"	"	
	03:00	(427)	50/3	7/3	ptly cldy	2	
		(428)	100/2	5/2	"	"	cut short by clouds
	06:00	(429)	200/3	10/3	ptly cldy	3	used long offsets
Sept. 26	01:00	(430)	150/3	14/3	ptly cldy	1	firing through holes in clouds
		(431)	50/0	7/0	ptly cldy	"	"
		(432)	100/2	9/2	"	"	"
	05:00	(433)	80/3	13/3	"	"	"
	07:00	(434)	100/0	7/0	clear	2	laser overheating
		(435)	100/3	13/3	"	"	"
Sept. 27	02:00	(436)	50/3	15/3	clear	2	
		(437)	120/0	19/0	"	"	
		(438)	120/2	11/2	"	"	
	05:00	(439)	75/3	21/3	"	1	
	07:30	(440)	100/3	11/3	"	2	offset from Carlini
Sept. 28	03:30	(441)	50/3	10/3	ptly cldy	2	A-11 in dark, offset from Schmidt
		(442)	50/2	11/2	"	"	
		(443)	100/0	9/0	"	"	
		(444)	50/3	10/3	"	"	
	05:30				cloudy		run cancelled
	09:30	(445)	200/3	10/3	clear	2	
Sept. 29	04:15	(446)	50/3	16/3	clear	1	tried offsets off Bruce to Lansberg A
		(447)	100/2	9/2	"	"	
		(448)	150/0	0/0	"	"	
	07:15	(449)	150/3	20/3	ptly cldy	1	offset from Carlini
	10:15	(450)	282/3	6/3	clear	2	"

STATION LOG, SEPT. - OCT. 1972

DATE	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Sept. 30	05:00	(451)	50/2	0/2	clear	4	seeing too bad for A-14
		(452)	138/3	11/3	clear	"	offset from Carlini
	08:00	(453)	147/3	0/3	clear	5	stopped by lack of contrast
	11:00				clear		poor seeing, no contrast
Oct. 1	06:00	(454)	150/2	5/2	clear	1	offset guide from Carlini
		(455)	50/3	16/3	"	"	to Flamstead A
		(456)	50/2	3/2	"	"	
	09:00	(457)	50/3	9/3	"	2	
	11:20	(458)	220/3	7/3	"	3-5	just barely visible
Oct. 2	07:00	(459)	100/3	9/3	clear	1	offset from Hershel D
	10:00	(460)	200/3	3/3	"	4	
	01:00				clear	?	cancelled, no contrast
Oct. 3	07:30	(461)	200/3	0/3	mod. cirrus	2	
	10:30-01:30				cirrus		runs cancelled for lack of contrast and cirrus

Oct. 4-9 New Moon

TOTALS FOR SEPT. OCT. LUNATION	TRIES	SUCCESSFUL RANGE MEASUREMENTS
	11/0	7/0
	0/1	0/1
	11/2	10/2
	31/3	28/3

STATION LOG OCT. - NOV. 1972

DATE	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Oct. 10 - Nov. 17							Working on spur gear
Nov. 18	1945				Clear	6-8	Telescope alignment
	2245				"	"	" "
	0145				"	"	Seeing too bad
Nov. 19	2030				Clear	5-6	Alignment difficulty
	2300	(462)	119/3	12/3	"	"	
	0200	(463)	192/3	11/3	"	4	
Nov. 20	2120	(464)	145/3	7/3	Clear	3-4	Heavy image motion
		(465)	218/0	5/0	"	"	
	2400	(466)	247/3	0/3	"	5	
	0300				Cloudy	5	
Nov. 21	2230				Foggy	8-10	Bad seeing, cancelled
	0130				"		
	0430				"		
Nov. 22	2315				Cloudy		
	0215				"		
	0515				"		
Nov. 23	Date Change						
Nov. 24	0000				Cloudy		
	0300				"		
	0600				"		
Nov. 25	0145	(467)	376/3	5/3	Clear	4-10	Windy
	0430	(468)	188/3	17/3	"	5	Very windy
		(469)	98/0	0/0	"	"	" "
	0645	(470)	197/3	13/3	"	4	
Nov. 26	0300	(471)	48/3	12/3	Clear	3-5	
		(472)	135/0	2/0	"	"	
		(473)	144/2	7/2	"	"	
		(474)	48/0	1/0	"	"	Offset not working properly
	0630	(475)	193/3	9/3	Clear	4-5	Realigned finder
	0900	(476)	250/3	7/3	"	"	Rough guiding
Nov. 27	0345	(477)	195/3	8/3	Clear	5-10	Windy
	0645				"		Too windy to open
	0945				"		" " " "

STATION LOG OCT. - NOV. 1972

DATE	TIME	RUN NO.	NO. OF SHOTS	RETURNS	WEATHER	SEEING	COMMENTS
Nov. 28	0430				Foggy		Cancelled
	0730				"		"
	1030				"		"
Nov. 29	0500				Cloudy		Cancelled
	0800				"		"
	1100				"		"
Nov. 30	0600				Clear	4-8	Computer drives not ready
	0900				"	"	

Dec. 1 - Dec. 5 New Moon Break

TOTALS FOR NOVEMBER

Attempts	Successful Range Measurements
4/0	1/0
0/1	0/1
1/2	1/2
11/3	10/3

TOTALS FOR QUARTER

Attempts	Successful Range Measurements
16/0	8/0
0/1	0/1
13/2	11/2
42/3	38/3

APPENDIX II

SYSTEM CALIBRATION DATA

SYSTEM CALIBRATION DATA

The following pages contain the calibration constants for the quarterly period covered by the present report. The catagories A through E are explained below.

A - This column contains the uncorrected calibration constant for the entire lunar ranging system as measured by a light emitting diode. It is approximately 5.5 nanoseconds higher than the final calibration value due to internal delays in the photodiode as well as geometric corrections.

B - This column shows the results of calibrating only the relative delays between the photodiode and photomultiplier sides of the ranging system using a separate time-to-pulse height converter and a pulse height analyzer.

C - This column gives the arithmetic mean of the feedback calibration return through the entire lunar ranging system as recorded during the actual lunar ranging by the system teletype.

D - This column shows results of subtracting the 2.9 nanosecond geometric correction from Column C. The units have been changed to tenths of nanoseconds and a minus sign added to coincide with how this additive constant appears on the preliminary data cards. Letters A, B, and C follow the corrected calibration constant to indicate the relative accuracy, where: A = $\pm$ 200 picoseconds; B = $\pm$ 400 picoseconds; and C = $\pm$ 600 picoseconds.

E - Column E, when shown, gives the results of correcting the calibration constant for an error in the vernier constants during the summer of 1972. Again, letters A, B, and C follow, indicating the relative accuracy.

ELECTRONIC CALIBRATION CONSTANTS AS AMMENDED ON
20 NOVEMBER, 1972

Date (GMT)	E
June 16	-254C
June 17	-260C
June 18	-259C
June 19	-261B
June 20	-259B
June 21	-259C
June 22	-254C
June 24	-254C
June 25	-254C
June 26	-270C
June 27	-262C
June 28	-262C
June 29	-251C
June 30	-243C
July 1	-263B
July 6	-273C
July 23	-268C
July 24	-268B
July 25	-267B
July 26	-276C
July 27	-269C
July 28	-278C

Date (GMT)	E
July 30	-262B
July 31	-262C
August 3	-258C
August 17	-265C
August 18	-262C
August 21	-261C
August 22	-263C
August 23	-263C
August 24	-262B
August 25	-266C
August 28	-262C
August 29	-262C
August 30	-267C
August 31	-264B
September 1	-265C

Calibration Data (September)

Date	A	B	C	D	E
Sept. 11 V = 2200 D = 190; A = 20 Tube #1; (255)	32.4	--	--	--	--
Sept. 12 (256)	32.9	--	--	--	--
Sept. 13 (257)	32.9	--	--	-268B	-264C
Sept. 14 (258)	32.8	--	--	--	--
Sept. 15 (259)	--	30.7	29.7A	-268A	-264B
Sept. 16 (260)	31.6	--	--	--	--
Sept. 18 (262)	32.0	31.0	29.7A	-268A	-264B
Sept. 19 (263)	33.2	30.9	29.7A	-268A	-264B
Sept. 20 (264)	31.0	--	--	--	--
Sept. 21 (265)	31.8	--	--	--	--
Sept. 22 (266)	32.3	--	--	--	--
Sept. 23 (267)	31.9	--	--	--	--
Sept. 24 (268)	33.7	--	29.9B	-270B	-266C
Sept. 25 (269)	31.9	--	30.2B	-273B	-269C
Sept. 26 (270)	31.6	31.3	30.4B	-275B	-271C
Sept. 27 (271)	31.4	--	30.0B	-271B	-267C
Sept. 28 (272)	32.3	31.0	--	-271B	-267C
Sept. 29 (273)	32.8	--	30.1A	-272A	-268B
Sept. 30 (274)	32.2	--	30.1B	-272B	-268C
Oct. 1 (275)	--	--	--	--	--
Oct. 2 (276)	32.0	31.3	29.9B	-270B	-266C
Oct. 3 (277)	33.7	--	30.0B	-271B	-267C

Calibration Data (November)

Date	A	B	C	D	E
November 20 (325) PMT #1; V = 3200; D = 190; G = 20	--	--	29.8B	-269B	-273C
November 21 (326)	--	29.0	30.6B	-277B	--
November 25	--	28.7	30.0B	-271B	--
November 26	--	--	29.2B	-263B	--
November 27	--	--	30.2B	-273B	--